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Hail Damage Variation by Seed Source in a Ponderosa Pine Plantation

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A Nebraska provenance plantation of ponderosa pine was evaluated after a severe hailstorm. Trees sustaining most damage were from Pacific Northwest, Bitterroot Valley (Montana), and southern Rocky Mountain seed sources. Trees from natural stands east of the Continental Divide have crown form and needle characteristics that incur less hail damage.

Keywords: *Pinus ponderosa,* seed sources, crown forms, hail damage

Management Implications

Landowners and foresters planting trees in areas with frequent, violent hailstorms are advised that certain species of trees are more susceptible to hail damage than others. The use of ponderosa pine seed sources from east of the Continental Divide and north of New Mexico is recommended to minimize hail damage.

Introduction

On September 11, 1977, a severe thunderstorm, accompanied by 60- to 90-mile-per-hour wind, heavy rain, and marble-sized hail (U.S. National Oceanic and Atmospheric Administration 1977) struck experimental provenance plantations of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), 3 miles east of Hastings, Nebr. The plantations consisted of trees from 79 seed sources collected throughout the natural range (mostly eastern) of ponderosa pine (fig. 1). The trees were 13 years old (10 years in the field) and averaged 8.6 feet tall. The many dead rabbits, ground squirrels, mice, and other small rodents floating in the water throughout the plantation after the storm were indicative of the storm's intensity.

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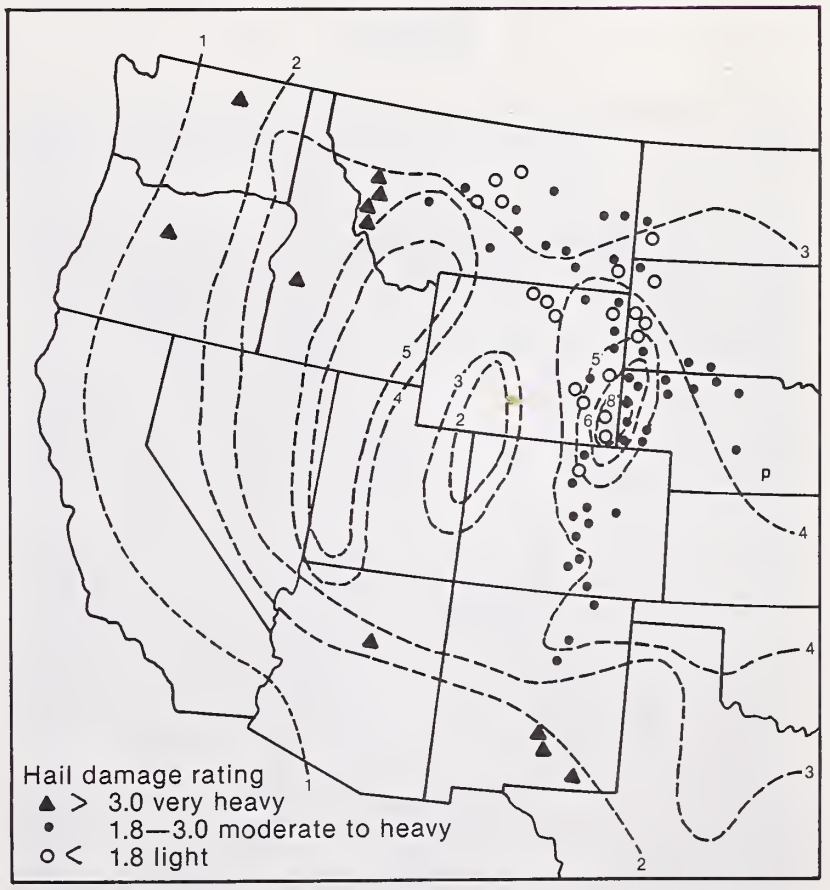

Figure 1.—Dots, circles, and triangles indicate the locations of 79 seed sources of ponderosa pine growing at the Hastings, Nebr., plantation (p). Isohyetal lines indicate average annual number of days with hail based on 200 first-order U.S. Weather Bureau stations, 1899-1938 (U.S. Department of Agriculture 1941).

Hail, driven by extreme winds, pelted the trees from a near horizontal trajectory. Damage to the trees was severe, and included loss of needles, bark, and cambium from the northwest side of the trees, the direction from which the storm approached (fig. 2). Piles of needles were found under each tree.

Observations indicated that trees from certain seed sources appeared more damaged than others. Therefore, one of the plantations was evaluated to determine if hail damage varied among the 79 seed sources of ponderosa pine.

Methods

The plantation was established in May 1968 with 2 + 1 bare-root stock. Each of the 79 seed sources is represented by 4-tree linear plots, replicated 15 times in randomized blocks. The plantation, with 30 north-south rows spaced 13 feet apart, covers about 10 acres on an open, level site.

A numerical rating, quantifying the extent of hail damage, was assigned to each 4-tree plot on July 5-7, 1978. The rating was a reflection of damage sustained by the trees on September 11, 1977, and their ability to recover during the first half of the 1978 growing season. A rating of 1 denoted that 0-25% of the original crown foliage was damaged, 2 = 26-50%, 3 = 51-75%, and 4 = 76-100%. Therefore, a rating of 1 indicated light hail damage and 4 indicated very heavy hail damage. Average hail damage ratings were computed for each of the 79 seed sources.

Results

Average hail damage ratings for seed sources ranged from 1.5 to 3.8 (table 1). The plantation average rating was 2.2. Trees of variety *ponderosa* from Oregon, Washington, Idaho, and western Montana, and trees of variety *scopulorum* from the southern Rocky Mountain areas of the ponderosa pine range were most heavily damaged. They are exclusively represented by the 11 seed sources having average ratings greater than 3.0 and are indicated in figure 1 by solid triangles. Trees from the Okanogan, Wash., source (866) and the Carlsbad, N. Mex., source (768) were most heavily damaged, with ratings of 3.8 (figs. 3 and 4).

Lightly damaged sources with average ratings of less than 1.8 (indicated by open circles in fig. 1) are predominately from eastern Wyoming, western South Dakota, and central Montana. The least damaged trees were from the Lewistown, Mont., source (815) and the Windham, Mont., source (753) both rated 1.5.

Because the storm moved through the plantation from northwest to southeast, trees on the west side and northwest corner of the rectangular plantation were damaged slightly more than those on the east side and southeast corner. This is reflected in the hail damage ratings which showed that the westernmost six rows had average hail damage ratings of 2.6 compared to the plantation average of 2.2. Because trees of each seed source were randomly located within the 15 blocks of the plantation, the storm's direction did not affect the relative differences found among seed sources. Trees from the northwestern United States and the southern Rocky Mountains were consistently much more heavily damaged than others, no matter where they were located in the plantation.

Figure 2.—The intense hailstorm removed needles, bark, buds, and cambium from the windward side of this tree, severely damaging it.

Discussion and Conclusions

Differences were observed between the crown form of damaged and undamaged trees. Heavily damaged trees from the Northwest and the Bitterroot Valley in western Montana tended to have narrow, thin crowns with few lateral branches per unit of stem length (fig. 5). When hail hit the crowns of these trees, it penetrated the lateral branches, knocking off bark and destroying the cambium on the northwest side of the main stem. Trees with dense, oval crowns, had many lateral branches per unit of stem length, denser foliage, and protected main stems. The brunt of the hail was absorbed by the laterals. Consequently, the main stems sustained less damage to the cambium and were better able to recover.

Other differences between severely damaged and lightly damaged trees appear to be related to needle characteristics. Average damage ratings by geographic areas may be compared with needle measurements taken on 3-year-old seedlings of the 79 seed sources in the nursery (table 2). Seedlings of trees from the Northwest, Bitterroot Valley, and southern Rocky Mountains, where hail is infrequent, generally have a very low percentage of appressed needles and 2-needle fascicles. Progenies of trees from these three geographic areas have mostly divergent needles (needles growing at right angles to the branches), with most fascicles having three and, occasionally, four needles. They sustained heavy hail damage. In contrast, progenies of trees from the

Table 1.—Tree heights, hail damage ratings, and annual days with hail at source locations for 79 ponderosa pine provenances planted at Hastings, Nebraska (seed sources grouped geographically)

Seed source number	State	Sample trees	10-year average height	Average hail damage rating[1]	Average annual days with hail[2]
		number	*feet*		*number*
866	Washington	43	7.2	3.8	1.0
865	Oregon	12	7.8	3.2	1.0
867	Idaho	17	8.8	3.1	3.0
817	Montana	14	7.3	3.4	3.0
818	Montana	12	6.9	3.3	2.5
819	Montana	54	8.2	3.6	2.5
820	Montana	17	7.9	3.1	2.5
816	Montana	60	9.5	2.8	3.5
754	Montana	59	9.0	1.9	3.0
753	Montana	48	8.3	1.5	3.0
811	Montana	59	10.2	1.9	3.0
812	Montana	58	8.6	1.7	3.5
813	Montana	59	8.0	1.7	3.0
814	Montana	60	8.9	1.9	3.0
815	Montana	58	8.3	1.5	4.0
727	Montana	60	8.1	2.0	2.8
826	Montana	57	8.5	1.8	2.8
702	North Dakota	59	8.5	1.9	3.5
701	North Dakota	59	8.9	1.7	3.2
821	Montana	60	9.4	2.0	3.6
822	Montana	59	10.3	1.9	3.0
823	Montana	60	9.3	1.8	3.0
824	Montana	59	9.2	1.9	3.0
825	Montana	60	10.0	2.3	3.4
827	Montana	59	9.4	2.1	3.4
828	Montana	60	9.4	1.7	3.8
703	South Dakota	60	9.2	1.8	3.5
704	South Dakota	58	8.8	1.7	3.7
829	Wyoming	59	8.3	1.7	3.7
830	Wyoming	60	7.2	1.6	4.0
831	Wyoming	60	7.5	1.7	4.0
832	Wyoming	59	9.5	1.9	4.2
833	Wyoming	60	9.8	2.1	4.3
834	Wyoming	58	8.2	1.7	4.4
835	Wyoming	60	9.0	1.9	4.8
836	Wyoming	59	8.6	1.8	5.1
837	South Dakota	60	9.7	1.7	4.5
838	South Dakota	59	7.6	1.7	5.0
839	South Dakota	60	8.6	1.7	4.6
840	South Dakota	59	9.1	2.3	5.2
851	Nebraska	60	8.4	2.3	6.6
722	Nebraska	59	8.8	1.8	6.2
852	Nebraska	60	9.9	2.4	4.6
853	Nebraska	59	8.9	2.1	4.5
855	Nebraska	47	9.3	2.7	4.0
854	South Dakota	60	9.1	2.2	3.9
757	South Dakota	57	11.0	2.6	3.8
721	Nebraska	60	11.0	2.3	3.8
720	Nebraska	59	11.8	2.2	3.7
856	Nebraska	50	8.4	2.9	3.9
849	Wyoming	60	8.8	1.9	5.0
850	Wyoming	60	7.7	1.7	5.8
848	Wyoming	60	7.3	1.7	4.6
847	Wyoming	60	8.0	1.7	5.0
846	Wyoming	59	8.0	1.6	8.0
857	Wyoming	60	7.1	1.7	8.0
723	Nebraska	59	9.0	2.2	8.0
845	Nebraska	60	8.4	1.9	9.0
844	Nebraska	58	7.1	1.9	9.0
758	Nebraska	60	7.8	1.9	7.0
759	Nebraska	60	9.1	2.2	7.0
858	Colorado	58	8.1	2.5	5.5
760	Colorado	60	6.6	1.7	5.0
761	Colorado	58	7.0	2.0	4.6
859	Colorado	58	8.1	2.4	5.0
724	Colorado	58	8.2	2.4	6.0
762	Colorado	60	7.2	2.3	5.5
763	Colorado	59	7.4	2.1	4.3
860	Colorado	60	7.4	2.3	4.1
861	Colorado	60	7.8	2.1	4.0
764	Colorado	59	9.3	2.1	3.9
765	Colorado	57	8.7	2.3	4.1
862	New Mexico	57	7.3	2.3	4.0
863	New Mexico	58	8.5	2.8	3.0
864	New Mexico	53	7.2	2.9	3.0
766	New Mexico	52	8.2	3.2	1.9
767	New Mexico	38	8.1	3.4	1.9
768	New Mexico	25	7.7	3.8	1.9
869	Arizona	25	7.8	3.4	2.3
Plantation total		4295			
Plantation means			8.6	2.2	

[1] *1 = light; 2 = moderate; 3 = heavy; 4 = very heavy.*

[2] *Data are a composite of readings obtained from maps in USDA (1941) and Changnon (1978).*

Figure 3.—The two badly damaged trees on the right are from the Okanogan, Wash., source (866) (hail damage rating = 3.8). The tree to the left, foreground, from the Medora, N. Dak., source (702) has only slight damage (hail damage rating = 1.9).

central Rocky Mountains east of the Continental Divide and Great Plains have more appressed needle growth and more 2-needle fascicles. They sustained less hail damage because of the greater protection provided by needles pressed closely along the branches, analogous to overlapping shingles.

Weidman's (1939) comparison of needles of trees from 20 seed sources collected throughout the natural range of ponderosa pine indicated that trees from east of the Continental Divide and north of New Mexico have short, thick, stiff needles, predominately in fascicles of two's; whereas trees from the Pacific Northwest, northwest Montana, and southern Rocky Mountains have long, thin, flexible needles, predominately in fascicles of three's. At Hastings, hail removed fewer needles from trees from the central Rocky Mountains east of the Continental Divide and Great Plains. Because needles in 2-needle fascicles are thicker and stiffer and offer more resistance than those in 3-needle fascicles, they are less susceptible to hail damage.

Considering these differences in crown form, needle characteristics, and corresponding hail damage, it seems reasonable to postulate that, through the long evolutionary process, hail-tolerant phenotypes of ponderosa pine developed in the central Rocky Mountains and the Great Plains of Colorado, Wyoming, Montana, Nebraska, and the Dakotas. Such trees are relatively tolerant to hail damage because of their dense crowns with many branches and their short, stiff, thick, appressed needles. Natural selection has ap-

Figure 4.—The three trees from the Carlsbad, N. Mex., source (768) in the row starting from left foreground to man pointing are badly defoliated (hail damage rating = 3.8). The trees in row on right, from the Ainsworth, Nebr., source (720) suffered average damage from hail (hail damage rating = 2.2).

Figure 5.—Trees in this square 25-tree plot, from the Lolo, Mont. source (818) typify the hail damage sustained by western Montana (Bitterroot Mountains) sources. This planting is adjacent to the 4-tree plot study area.

Table 2.—Average hail damage ratings in field plantation (age 10), compared with seedling needle traits in the nursery (age 3), by geographic areas

Geographic areas seed sources	Number of sources	Average hail damage rating[1]	Seedlings with appressed needles[2]	Seedlings with 2-needle fascicles[2]
			percent	*percent*
Northwest, Washington, Oregon, Idaho	3	3.4	5	1
Bitterroot Mountains, Montana	4	3.4	2	0
Westcentral Montana	3	2.1	13	3
Northcentral Montana	5	1.8	23	19
Eastern Montana, North Dakota	4	1.9	25	20
Southern Montana, South Dakota	9	1.9	28	24
Northcentral Wyoming	4	1.7	27	22
Black Hills, Wyoming, South Dakota	8	1.9	32	29
Northern Nebraska, South Dakota	10	2.3	20	24
Southeast Wyoming, Southwest Nebraska	11	1.9	30	35
Northern Colorado	6	2.2	23	27
Southern Colorado	5	2.2	22	17
Northern New Mexico	3	2.7	12	1
Southern New Mexico, Arizona	4	3.4	6	1
Plantation total means	79	2.2	22	20

[1] *1 = light; 2 = moderate; 3 = heavy; 4 = very heavy.*
[2] *Data from Read (1980).*

parently favored these characteristics in the regions where hail is common and severe.

For comparison, isohyetal lines representing the average annual number of days with hail were superimposed over seed source locations in fig. 1. They indicate that, in general, hail is less frequent in the northwestern states and in the southern Rocky Mountains (native areas of the trees most heavily damaged by hail at Hastings, Nebr.); hail is more frequent east of the Continental Divide, especially in Wyoming. However, these isohyetal lines include no information concerning hailstone size, wind accompanying hail, or number of hailstones falling per unit of area, all of which influence hail damage. Changnon (1978) developed, for portions of the western United States, "hail intensity" ratings which include these three characteristics of hailstorms. He found that there are more hailstorms with more and larger hail stones along the lee side of the eastern Rocky Mountains (i.e., the High Plains from New Mexico to Alberta) than elsewhere in the country. Changnon concluded that this area has the greatest hail intensity in the continental United States. Trees of the 11 most damaged sources originated from areas where hailstorms are both less frequent and less intense. The authors conclude that knowledge of hail intensity in the regions from which seed is to be collected is an essential aspect in the selection of seed sources to be planted in areas of the Great Plains where hail commonly occurs.

This ponderosa pine plantation has recovered remarkably well from the storm. The hail killed only a few trees, and they were all from the highly susceptible northwestern sources. Considerable new needle growth was observed throughout the plantation the first growing season following the storm. Because many of the buds were damaged by hail, new growth has emanated from needle fascicle buds. Buds of this type are latent in needle bases of all pines, and any sudden loss of needles or other shock will activate them (Mirov 1967).

Mortality and damage from the hailstorm on introduced species of conifers growing at the Hastings site were considerably greater than for ponderosa pine. Austrian pine (*Pinus nigra* Arnold) and Scotch pine (*Pinus sylvestris* L.) were severely damaged. Trees in a pitch pine (*Pinus rigida* Mill.) plantation sustained the most damage with approximately 80% mortality. Mortality to eastern redcedar (*Juniperus virginiana* L.), native to the Great Plains, was negligible. In areas with frequent, violent hailstorms, ponderosa pine should be among preferred conifer species for planting, with seed sources from east of the Continental Divide and north of New Mexico most desirable.

Literature Cited

Changnon, Stanley A., Jr. 1978. The climatology of hail in North America. American Meteorological Society Monograph 38:107-128.

Mirov, N. T. 1967. The genus *Pinus*. 602 p. Ronald Press Co., New York, N.Y.

Read, Ralph A. 1980. Genetic variation in seedling progeny of ponderosa pine provenances. Forest Science Monograph 23, 59 p.

U.S. Department of Agriculture. 1941. Climate and man, yearbook of agriculture. 1248 p. U.S. Government Printing Office, Washington, D.C.

U.S. National Oceanic and Atmospheric Administration. 1977. Storm data 19(9).

Weidman, Robert H. 1939. Evidence of racial influences in a 25-year test of ponderosa pine. Journal of Agricultural Research 59:855-887.